Trax Retaining Wall

4th street and Route 66

CENE 486C Final Presentation

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WEW

Project Purpose

Photo 1: Site image of the Project Parcel (looking East)

Project Purpose

The purpose of the project is to design a retaining wall for a proposed Holiday Inn that runs parallel with the railroad and proposed FUTS path.

Project Objectives

- Collect soil samples from project location.
- Conduct geotechnical testing and analysis on soil collected.
- Design 3 preliminary wall designs to present to client.
- Determine final wall design and create a construction plan and final cost.

Project Client: Steve Irwin
Technical Advisor: Thomas Nelson

Project Location

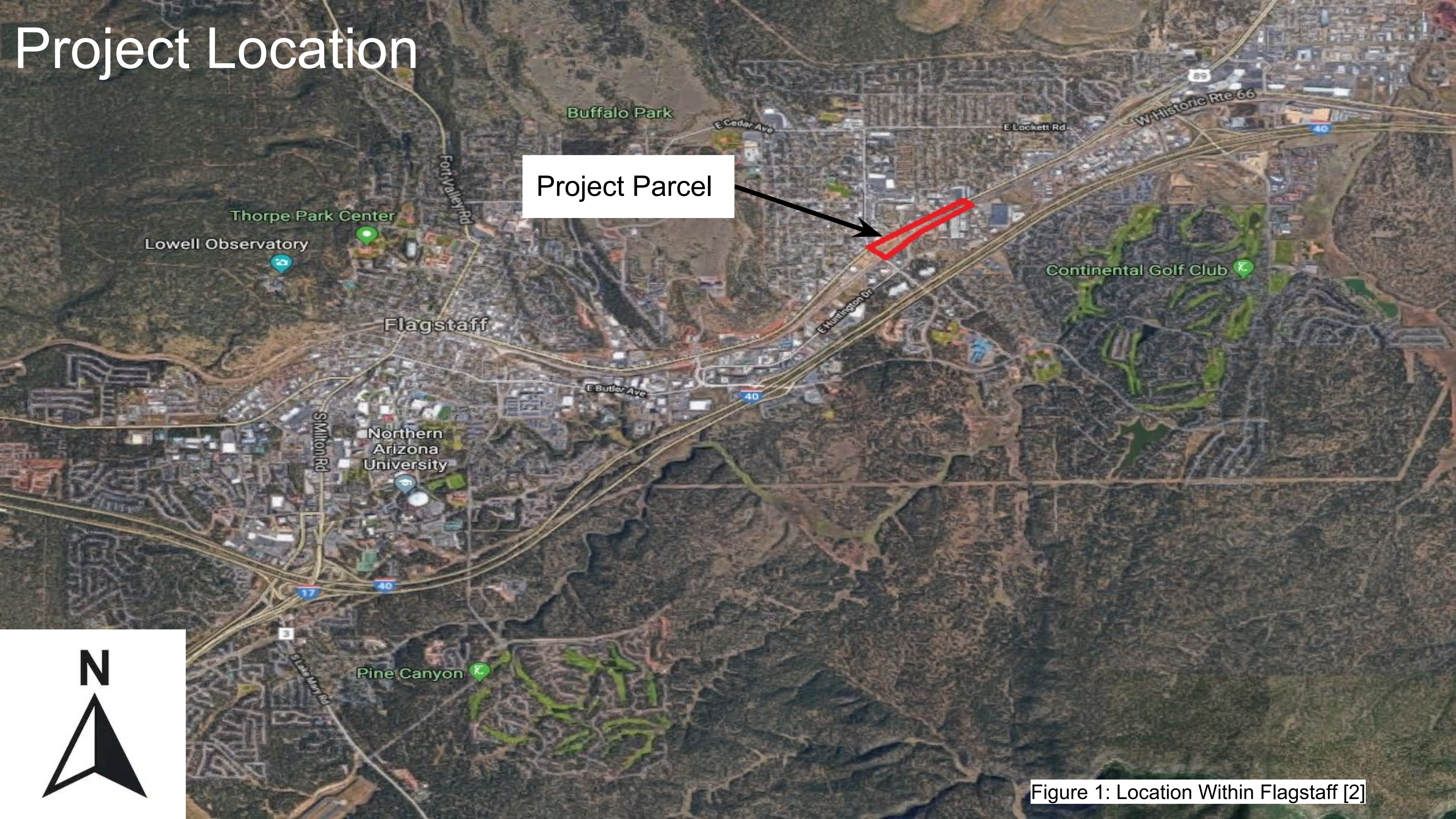


Figure 1: Location Within Flagstaff [2]

Project Location Continued

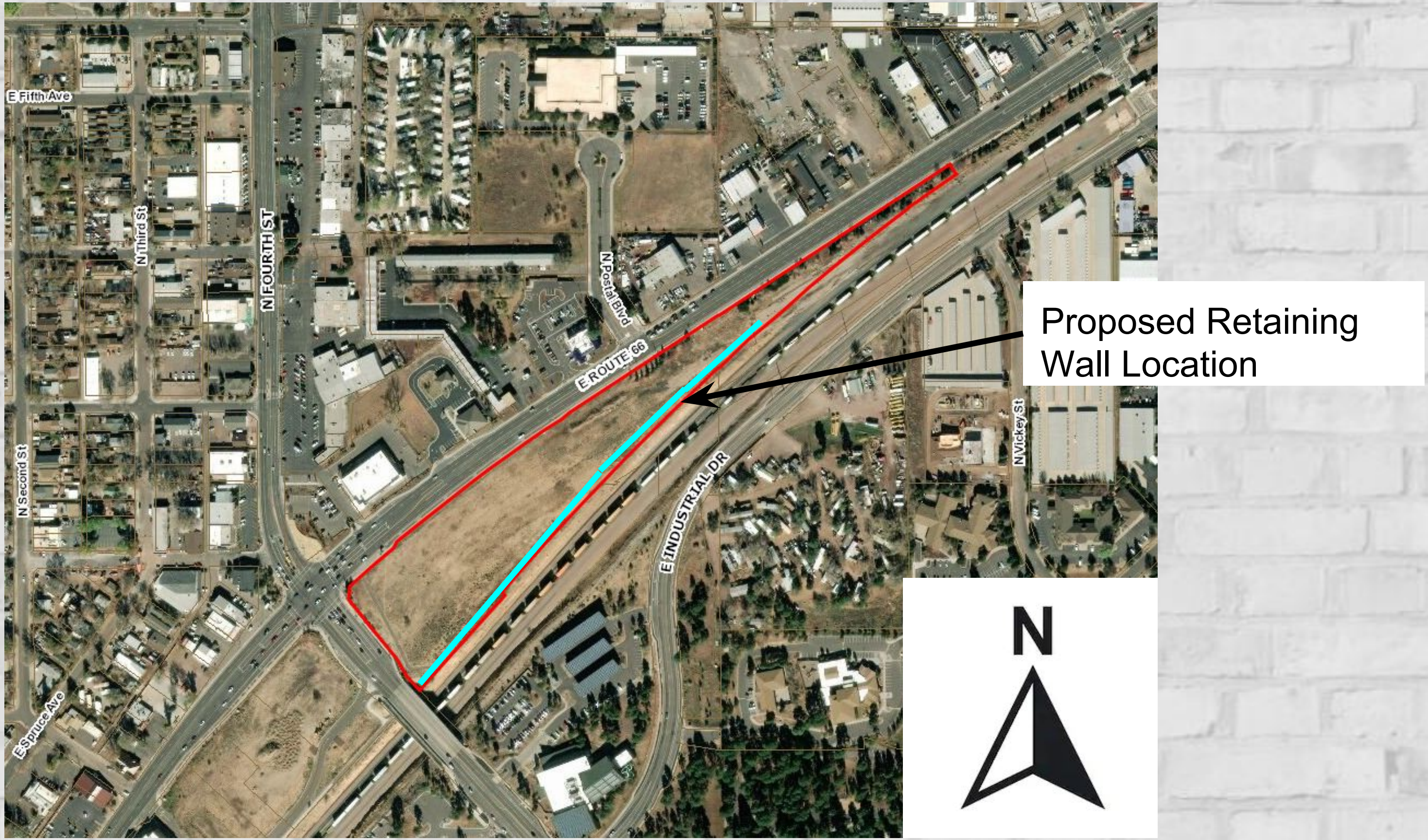


Figure 2: Location Relative to Surroundings [1]

Soil Sampling Plan

- Soil was collected from a stockpile located on the North side of the parcel.
- Stockpile had heavy vegetation, gravel, sand, and clay.
- Equipment used to collect soil:
  - Shovel
  - Labeled 5 gallon buckets
  - Tape measure

<u>Soil Collection</u>

- The stockpile was broken up into 6 sections to collect 6 homogenous samples.
- 4 samples were collected to create 1 sample per section.
- Samples holes were about foot deep horizontally, and a foot in diameter.
- Soil was placed in the buckets to create 6 samples for testing.

Photo 2: Soil Pile

Photo 3: Sample Hole

Photo 4: 6 Sample Buckets

Soil Sampling Map

Figure 3: Soil sampling map location [1]

Geotechnical Analysis and Testing

Soil Classification

- Soil Particle Size Distribution (ASTM D6913)
- Hydrometer (ASTM 7928-17)
- Atterberg Limits (ASTM D4318-17)
  - Liquid Limit
  - Plastic Limit
  - Plasticity Index

Unit Weight of Soil

- Modified Proctor Compaction (ASTM 1557-12e1)

Soil Settlement

- Consolidation (ASTM D2435)

Friction Angle of Soil

- Unconsolidated-Undrained Triaxial Compression Test (ASTM 2850-15)
- Direct Shear (ASTM D3080)

Figure 4: ASTM Logo

Soil Particle Size Distribution- ASTM D6913 [3]

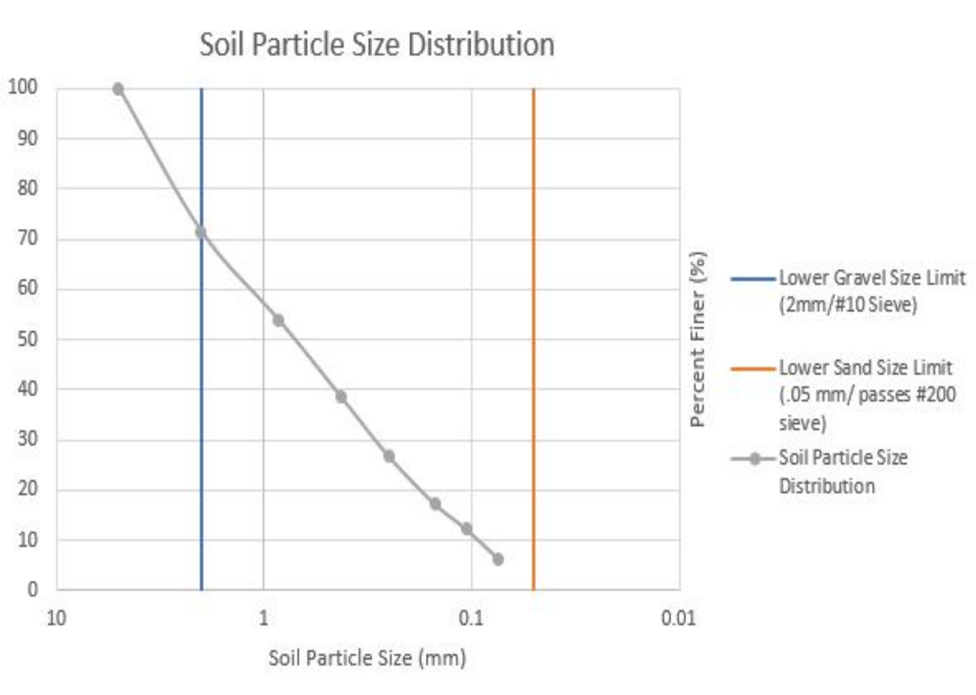


Figure 5: Granular (Greater Than #200 Sieve) Particle Size Distribution Curve

Table 1: Granular Particle Size Distribution

Type of Soil	Sieve Number	Particle Size (mm)	Percentage (%)
Gravel	10 > X	2 > X	28.53
Sand	10 > X > 200	2 > X > .05	67.07
Silt/Clay	X > 200	.05 > X	4.4

Photo 5: Sieve Stack

Particle Size Distribution of Fine-Grained Soils Using Sedimentation (Hydrometer) Analysis (ASTM 7928-17)

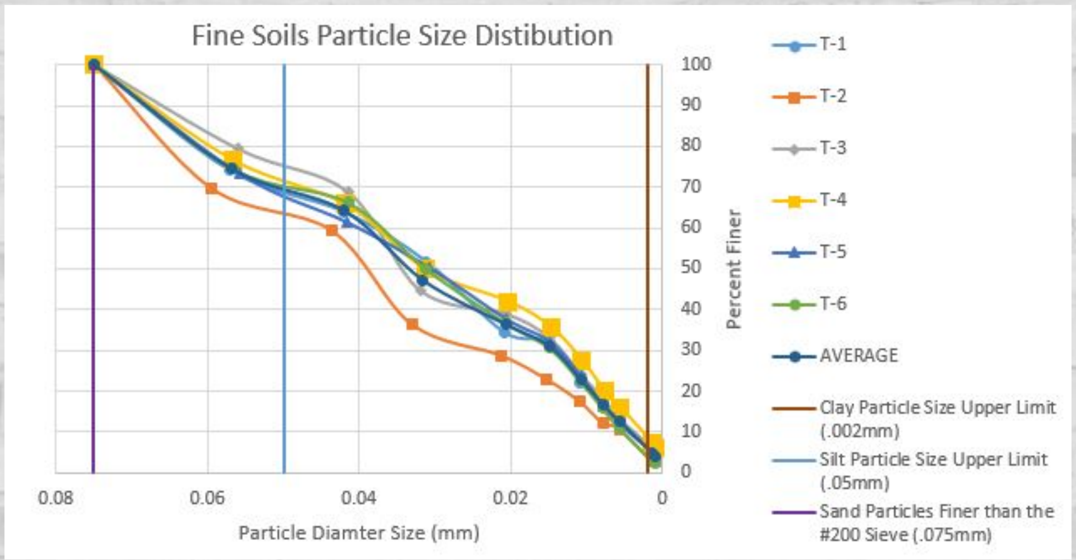


Figure 6: Fine Soil Particles Distribution

Photo 6: 6 Testing Samples and Control

Table 2: Fine Soils Contents as Percentage of Soils Passing the #200 Sieve

Type of Soil	Sieve Number	Particle Size (mm)	Percentage (%)
Sand	X > 200	X > 0.05	30.13
Silt	X > 200	.05 > X > 0.002	63.5
Clay	X > 200	0.002 > X	6.37

Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D4318-17)

Table 3: Plastic Limit Results

Plastic Limit						
Moisture Can ID	T-1	T-2	T-3	T-4	T-5	T-6
Mc (g)	19.5	13.3	19.8	13.6	13.2	13.3
Mm (g)	31.6	25.2	27.5	24.2	31	22.4
Md (g)	29.2	23.2	26	22.2	27.7	20.7
w (%)	24.74	20.20	24.19	23.26	22.76	22.97
PL (%)	24.74	20.20	24.19	23.26	22.76	22.97
AVG PL (%)	23.02	±1.58				

Photo 7: Liquid Limit Testing (Casagrande Cup)

Plastic Limit= 23.02%
Liquid Limit = 24.92 %
Plasticity Index = 1.9

Soil Classification (AASHTO System)

Figure 5.3 Flow chart for soil classification using the AASHTO system.

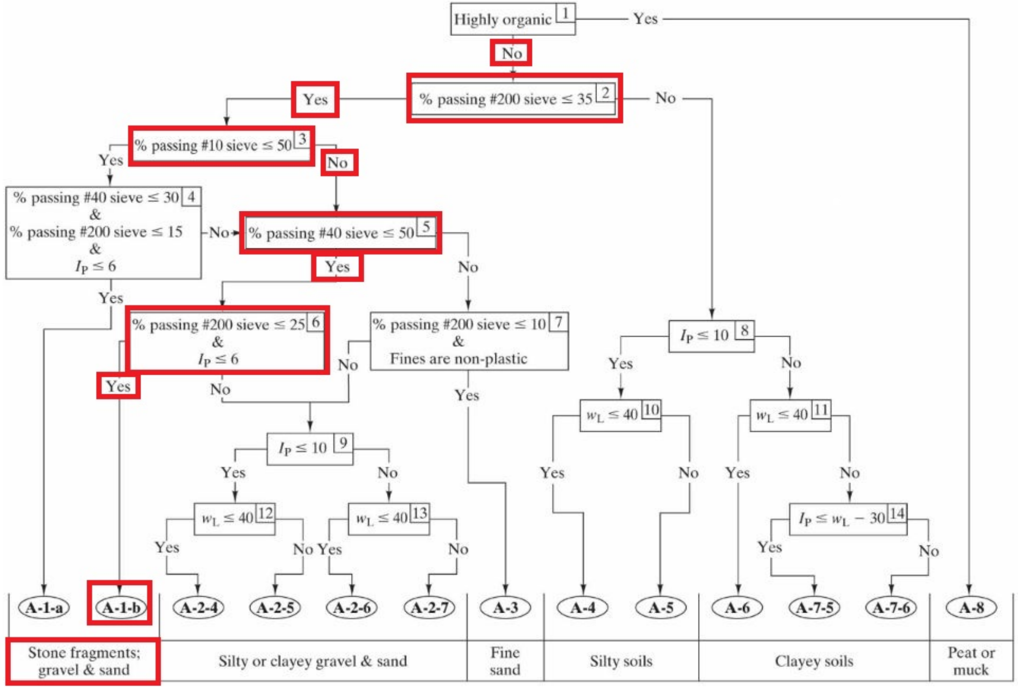


Figure 7: (Above): AASHTO Flow Chart for Soil Classification (Gravel not excluded)

Table 4: All Classification System Results

Classification Method	Classification Description	Soil Description
AASHTO	A-1-b , A-3	Gravel Sand/ Fine Sand
USCS	ML, SW	Welly Graded Sand with Gravel
USDA	N/A	Sand

Table 5: Soil Percentage Breakdown

Type of Soil	Particle Size (mm)	Percentage (%)
Gravel	2 > X	28.53
Sand	2 > X > .05	65.11
Silt	.05 > X > 0.002	5.8
Clay	0.002 > X	0.56

Laboratory Compaction Characteristics of Soil using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3)) (ASTM1557-12e1)

Table 8 (below): Modified Proctor Compaction Tabular Results

Modified Proctor Compaction- Average					
Trial	1	2	3	4	5
moisture content %	0.04	0.082	0.116	0.163	0.201
Std Dev Moisture Content	0.003	0.012	0.005	0.006	0.009
weight of compacted soil (g)	1571.9	1675.7	1803.6	1919.3	1845.2
moist unit weight (kg/m^3)	1667.6	1777.8	1913.6	2036.2	1955.3
dry unit weight (kg/m^3)	1588.1	1619.7	1684.6	1751.2	1628.6
Std Dev Dry Unit Weight	23.3	17.8	14.8	21.1	11
Optimal dry unit weight (kg/m^3)	1752				
Optimal dry unit weight (lb/ft^3)	109.37				

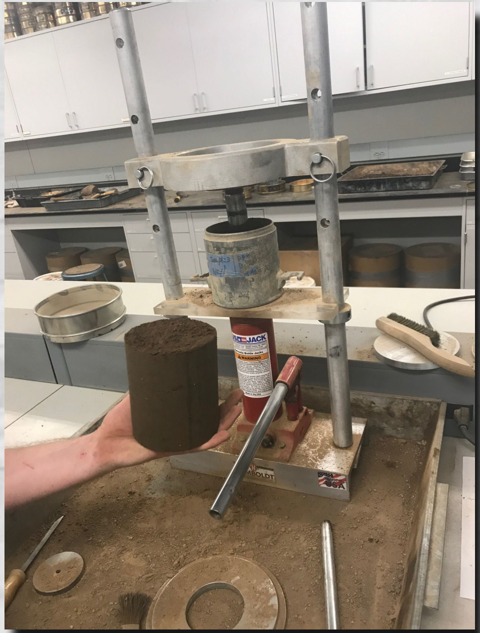


Photo 8: Compacted Soil Specimen

Consolidation-ASTM D2435

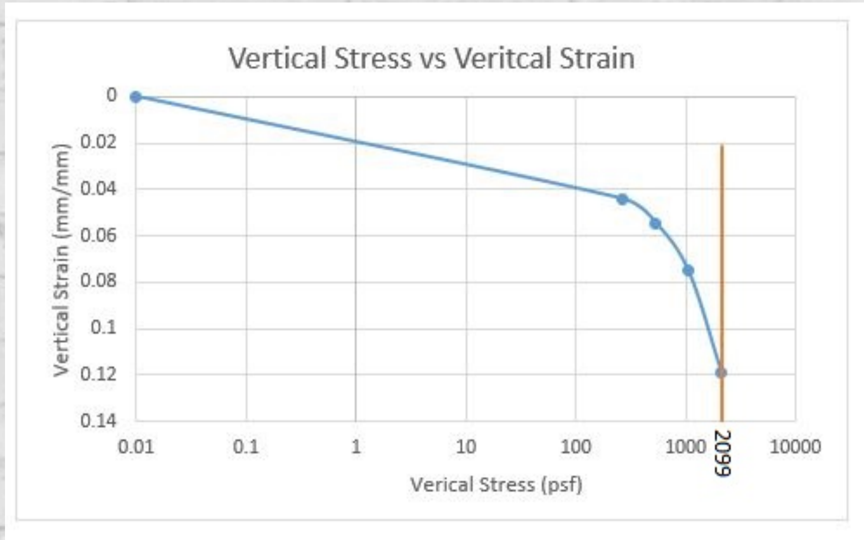


Figure 8: Log Vertical Stress vs Vertical Strain

Photo 9: Sample After Testing

Photo 10: Testing Equipment

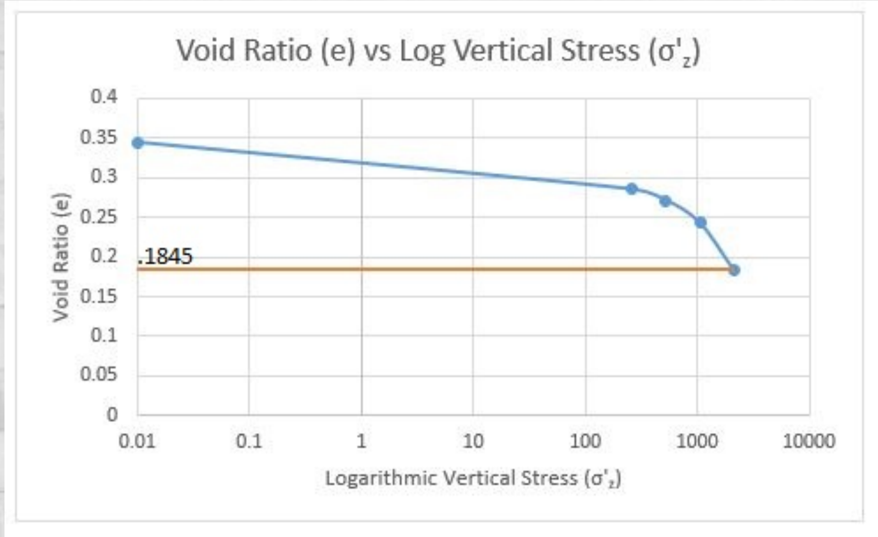


Figure 9: Void Ratio Compared to Applied Vertical Stress

Direct Shear-ASTM D3080

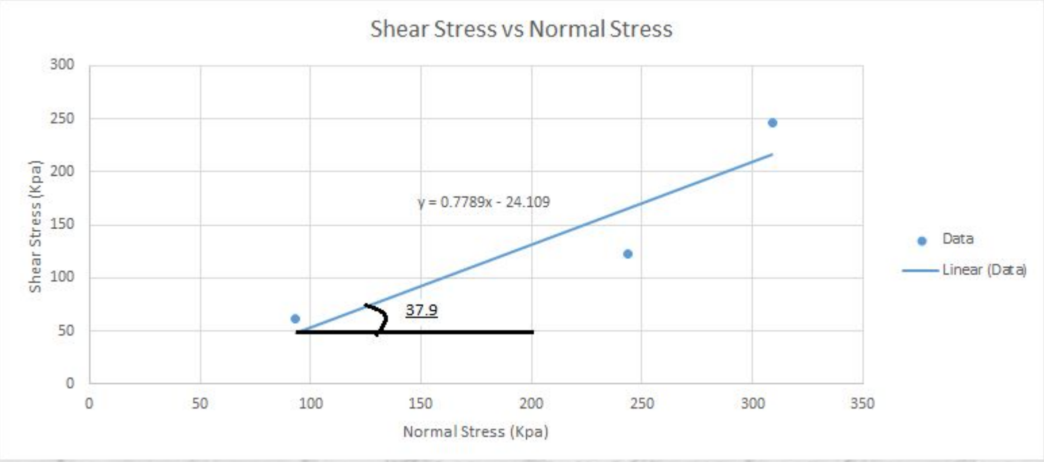


Figure 10: Friction Angle Determination

- Friction angle = 37.9
- Unconsolidated-Undrained Triaxial Compression test completed with inconclusive results

Photo 11: Direct Shear Testing Equipment

Photo 12: Testing Device

Heavy Metals Test Results:

Table 9: XRF Possible Soil Contaminant Results

Contaminant	Detected Average (ppm)	Error (ppm)	**Threshold (ppm)
Strontium (Sr)	432.736	6.273	47000
*Molybdenum (Mo)	4.65	3.823	390
*Cadmium (Cd)	11.57	9.281	39
*Tin (Sn)	10.999	5.459	47,000
*Anitmony (Sb)	23.497	8.543	31
*Mercury (Hg)	8.94	7.887	23
*Uranium (U)	6.78	6.263	16
Lead (Pb)	30.285	4.815	400
*Arsenic (As)	9.545	3.972	10
Titanium (Ti)	6108.038	110.705	310,000
Vanadium (V)	117.1	26.518	78
Cromium (Cr) III	37.968	9.311	120,000
Manganese (Mn)	876.202	62.398	3300
*Cobalt (Co)	165.05	144.583	900
Nickel (Ni)	62.642	16.319	1600
Copper (Cu)	45.801	12.335	3100
Zinc (Zn)	101.065	9.23	23,000

Table 10: Associative Notes for Table 9

Symbol	Note
*	These elements had samples which did not meet the minimum limit of detection (LODs), an thus were not accounted for in the average.
**	Arizona Admin. Code for Residential Limits of Remediation

Wall Option Screening Decision Matrix

Table 10: Seven Wall Preliminary Decision Matrix

Decision Matrix Criteria	Concrete Gravity Wall	Concrete Cantilever Wall	Reinforced Concrete Cantilever Wall	Anchored Retaining Wall	Mechanically Stabilized Earth	Concrete Masonry Unit	Geotextile Wall
Foundation Size (6 inch restriction)	-1	0	0	1	1	-1	0
Required Reinforcement (Amount needed)	1	1	-1	-1	0	1	0
Wall Aesthetics (Doesn't stand out)	-1	0	0	-1	1	1	1
Estimated Construction Time	1	0	0	-1	-1	1	-1
Sum	0	1	-1	-2	1	2	0

Table 11: Decision Matrix Key

Decision Matrix Key	
Point Value	Description
-1	The wall does not meet the teams requirements and is not practical for wall size or construction.
0	The wall does not have a negative or positive impact on the surroundings. The wall will meet requirements, but is not the best option.
1	The wall exceeds expectations and is practical for design in this category.
(yellow)	Selected walls for design.

Design Alternatives Overview

Concrete Cantilever Retaining Wall

- Cast-in-place wall that uses concrete and rebar reinforcements.
- Utilizes normal weight concrete.

Mechanically Stabilized Earth Retaining Wall

- Composite structure consisting of alternating layers of backfill that is compacted with soil reinforcement that ties to the back of the wall.
- Reinforcement is the attached to a wall facing to retain soil.

Concrete Masonry Unit Retaining Wall

- A mixture of a concrete foundation and a CMU block facing.
- Uses rebar through out both CMU and concrete foundation.

Preliminary Concrete Cantilever Retaining Wall

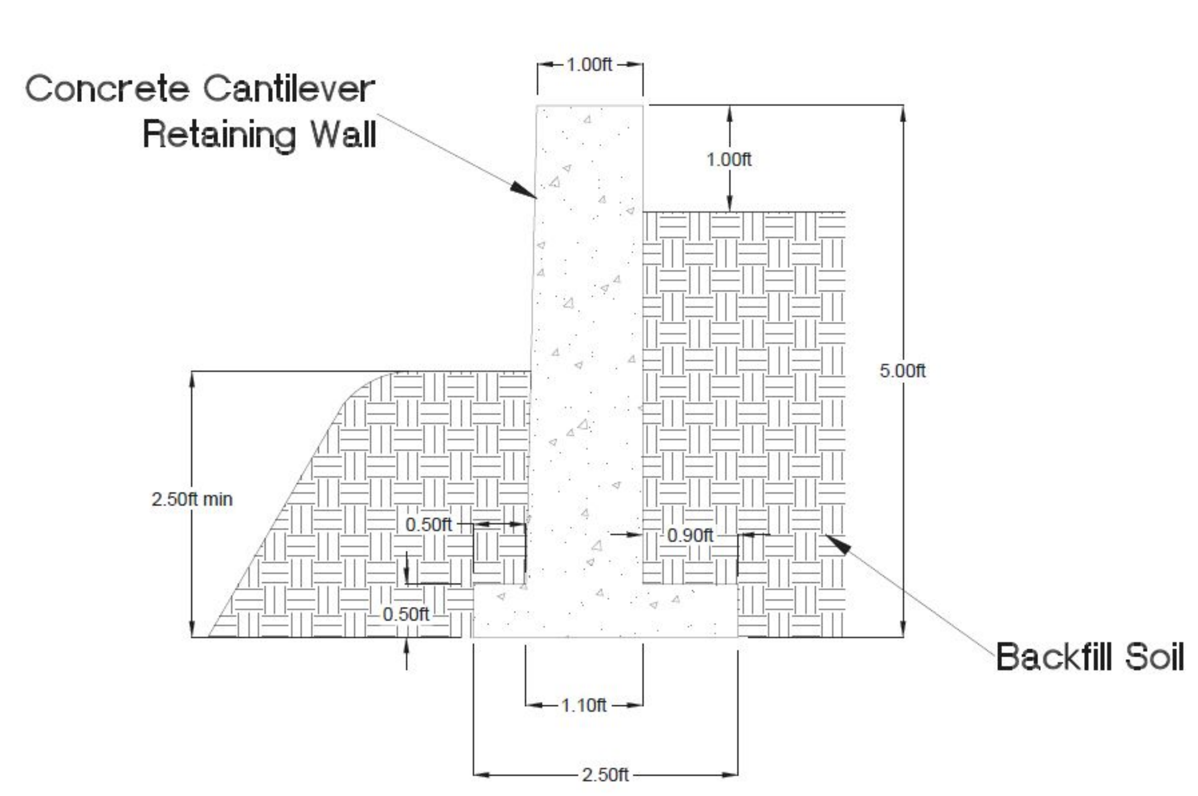


Figure 11: Concrete cantilever retaining wall cross-section

Table 12: Factor Safety Checks for Cantilever

Factor of Safety Check		
Overturning Factor of Safety	F.S.	3.1>3
Sliding Factor of Safety	F.S.	5.6>1.5
Bearing Factor of Safety	F.S.	12.8>3

- Cast in place wall
- No reinforcement designed
- Steps proposed along wall

Preliminary Mechanically Stabilized Earth Retaining Wall Design

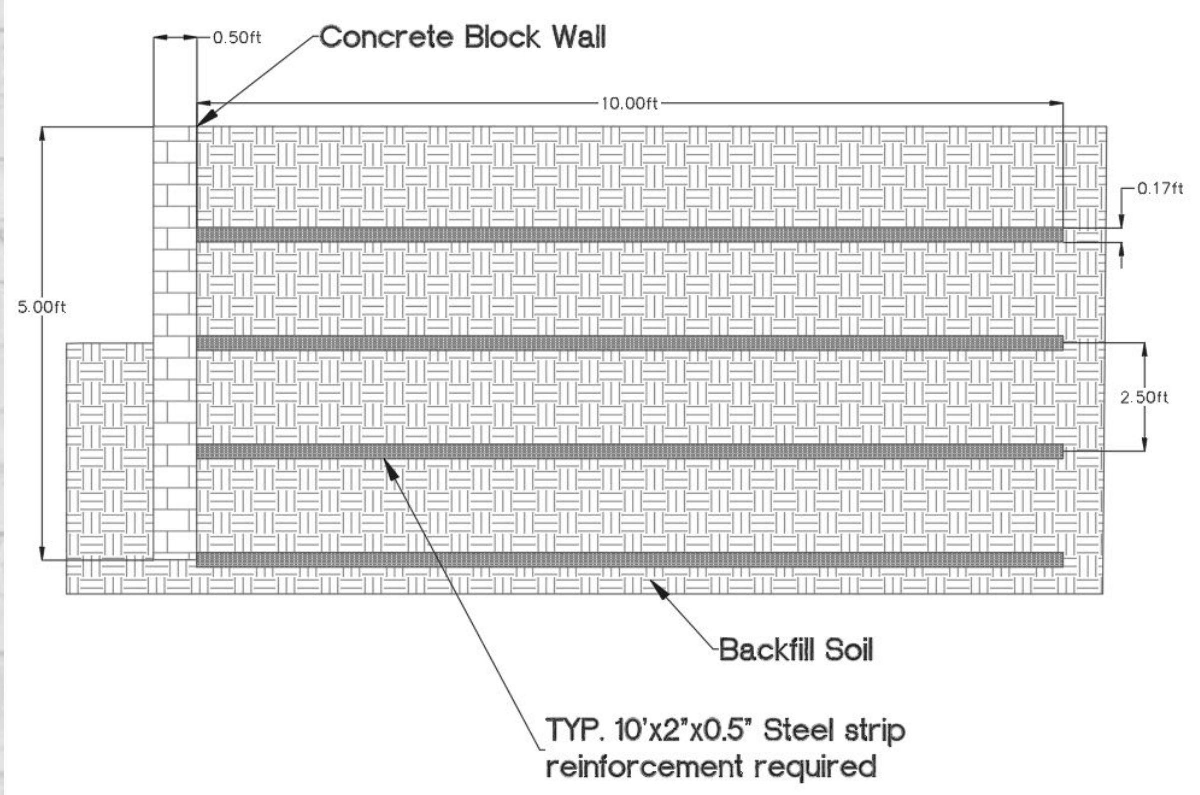


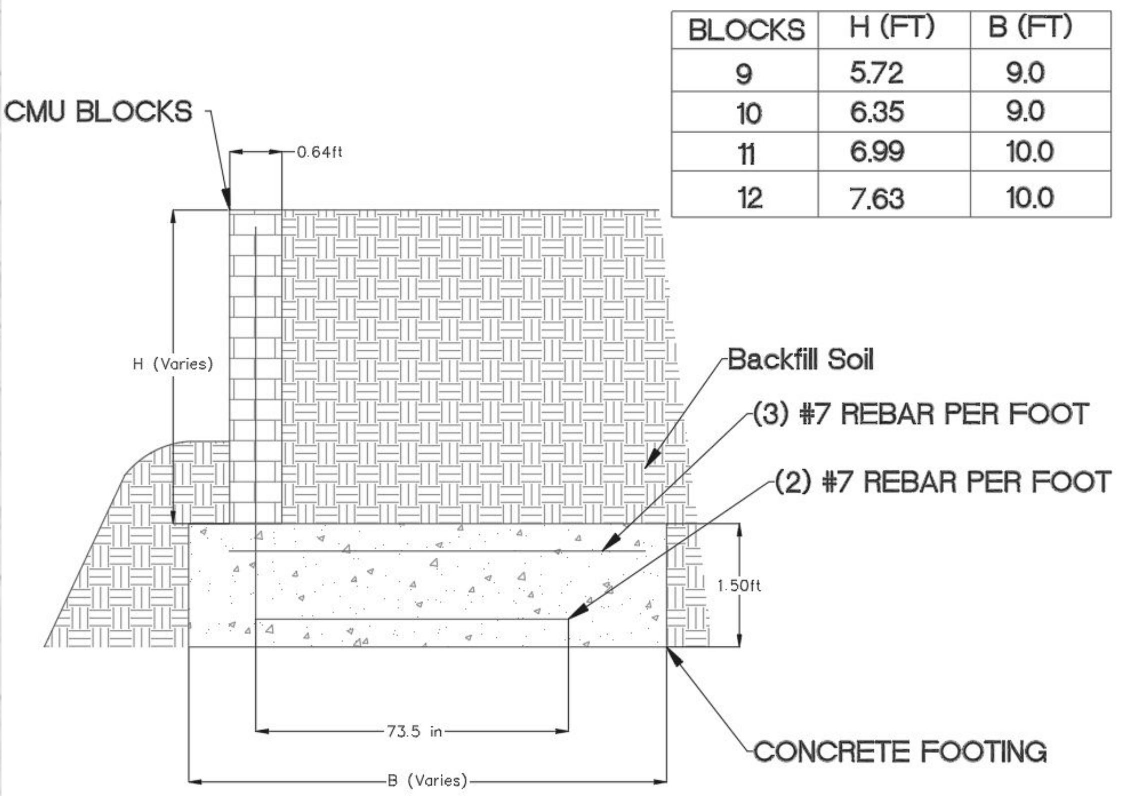
Figure 12: MSE retaining wall cross-section

Table 13: Factor of Safety checks for MSE Wall

Factor of Safety Check		
Overturning Factor of Safety	FS	24.5 > 3
Sliding Factor of Safety	FS	3.9 > 3
Bearing Factor of Safety	FS	48 > 5

- Mechanically Stabilized Earth (MSE)
- Steps proposed along wall

Preliminary CMU Retaining Wall Design



BLOCKS	H (FT)	B (FT)
9	5.72	9.0
10	6.35	9.0
11	6.99	10.0
12	7.63	10.0

Figure 13: CMU retaining wall cross-section

Table 14: Factor of Safety Checks for CMU Wall

Factor of Safety Check		
Overturning Factor of Safety	FS	5.1 > 3
Sliding Factor of Safety	FS	1.6 > 1.5
Bearing Factor of Safety	FS	7.9 > 3

- Concrete Masonry Unit (CMU)
- Steps proposed along wall
- Height varies along wall
- Footing length varies as the height of wall varies
- #7 Rebars required

Preliminary Retaining Wall Designs Decision Matrix

Table 15: Final wall selection decision matrix

Decision Matrix Criteria	Concrete Cantilever Wall	Mechanically Stabilized Earth	Concrete Masonry Unit
Drainage Natural and with the ability to add weep holes.	1	1	1
Foundation Size Size of foundation as the wall is restricted by the railroad and the FUTS trail for proposed Holiday Inn	0	1	0
Required Reinforcement How much reinforcement is required to build the wall based on cost and the ability for contractor to implement	1	0	0
Wall Aesthetics How the wall blends with natural surroundings and infrastructure	-1	0	1
Estimated Material Cost The overall cost of materials for the contractor to build the 1500 ft wall	1	-1	0
Estimated Construction Time The time it takes to construct the wall and the man hours that are required to implement the wall	-1	0	1
Sum	1	1	3

Concrete Masonry Unit (CMU)-

- Foundation Size-
  Large, however, fits within project restrictions.
- Wall Aesthetics-
  Wall is common in Flagstaff, matches existing
- Material Cost/Construction Time-
  Materials like CMU blocks are local to Flagstaff, and common wall building material.

Factor of Safety Design Check: Bearing Capacity

Table 16: CMU Bearing Capacity Check

# of Blocks	Height of Blocks (feet)	Total Height of Wall (feet)	Base Dimension of Footing (feet)	Depth of Footing (feet)	Factor of Safety (Bearing) ≥2
12	7.63	9.13	10	5	10.17
11	6.99	8.49	10	5	10.59
10	6.35	7.85	9	5	8.55
9	5.72	7.22	9	5	8.82

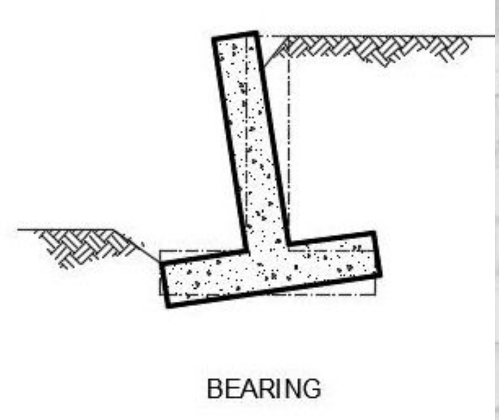


Figure 14: Bearing Failure

Factor of Safety Design Check: Overturning

Table 17: CMU Overturning Check

# of Blocks	Height of Blocks (feet)	Total Height of Wall (feet)	Base Dimension of Footing (feet)	Depth of Footing (feet)	Factor of Safety (Overturning) ≥3
12	7.63	9.13	10	5	3.56
11	6.99	8.49	10	5	3.68
10	6.35	7.85	9	5	3.09
9	5.72	7.22	9	5	3.19

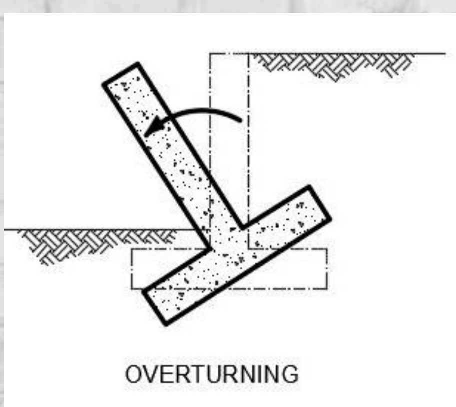


Figure 15: Overturning Failure

Factor of Safety Design Check: Sliding

Table 18: Decision Matrix Key

# of Blocks	Height of Blocks (feet)	Total Height of Wall (feet)	Base Dimension of Footing (feet)	Depth of Footing (feet)	Factor of Safety (Sliding) ≥1.5
12	7.63	9.13	10	5	2.16
11	6.99	8.49	10	5	2.16
10	6.35	7.85	9	5	2.06
9	5.72	7.22	9	5	2.06

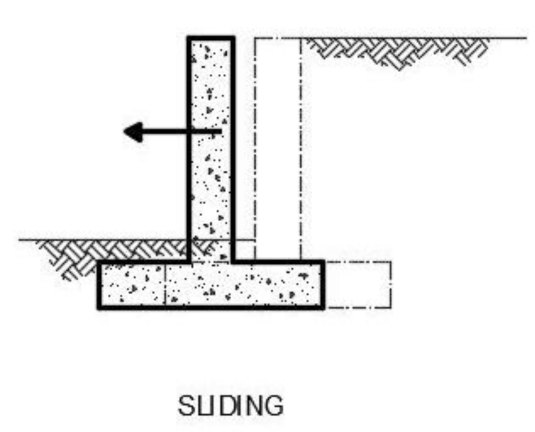


Figure 16: Sliding Failure

Wall Alignment

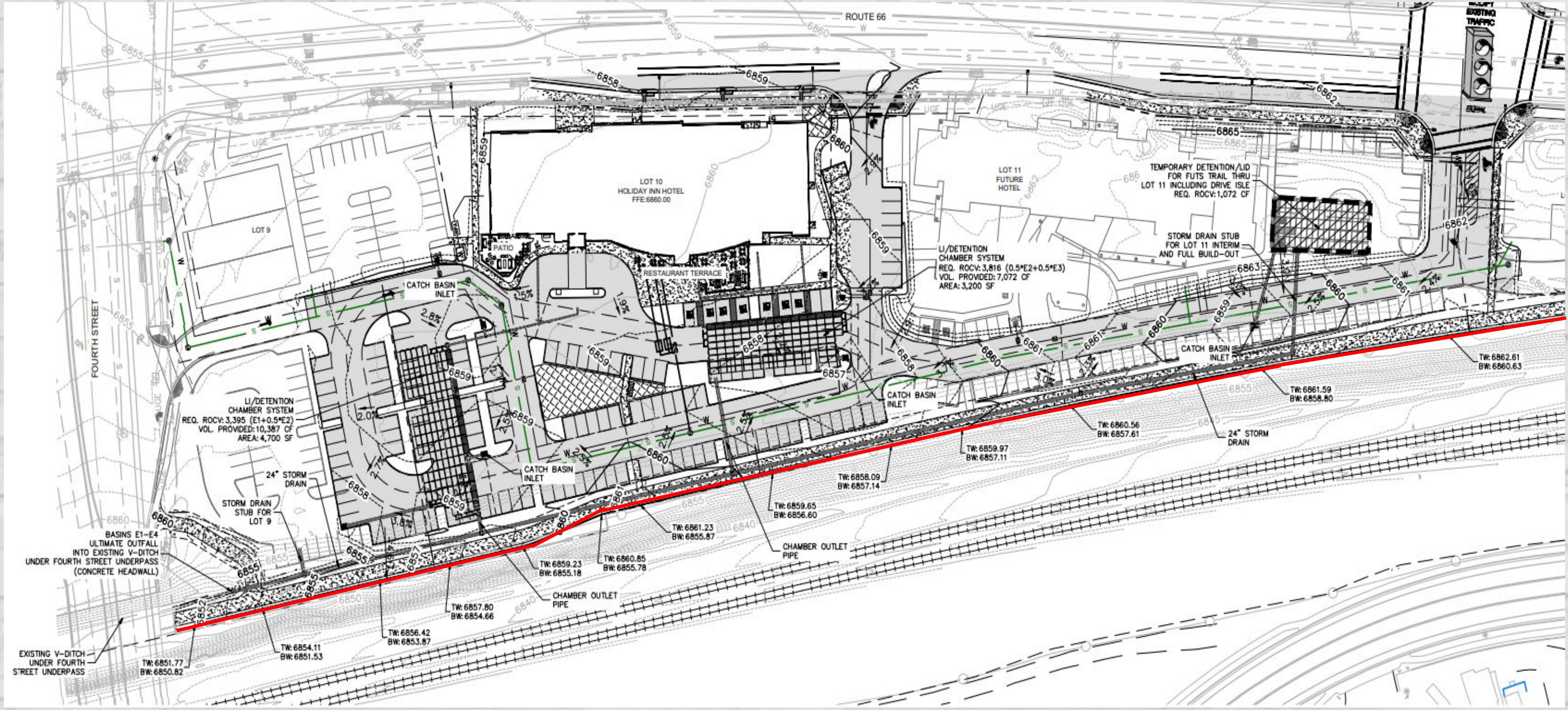


Figure 17: Grading and Drainage of the Proposed Construction of the Parcel. (Received from Shephard Wesnitzer Inc.)

Profile View of Final CMU Wall Design

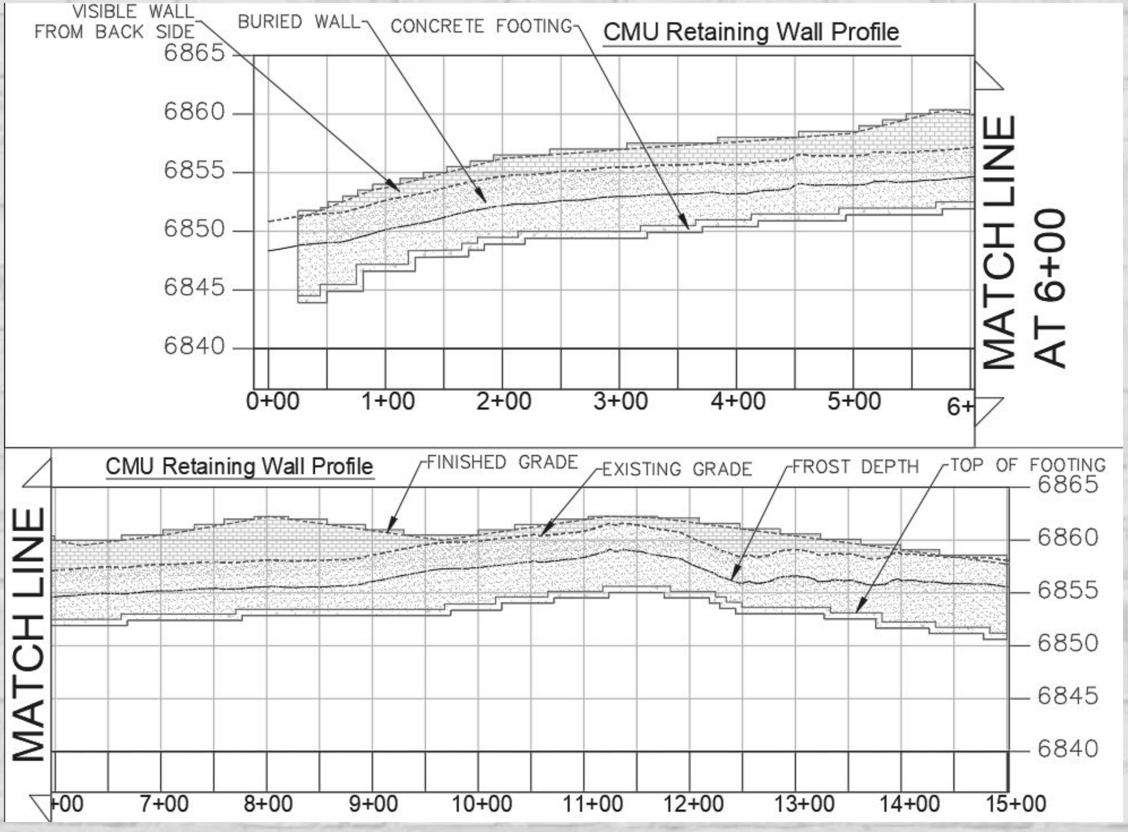


Figure 18: CMU retaining wall profile

Figure 19: CMU Blocks

- Top and bottom steps occur at different stations
- Height of wall varies along the profile
- Footing maintains 1.5’ thick and is below the frost depth
- Profile hatch shows the visible wall from the back side
- FUTS handrail proposed on top of the wall per City of Flagstaff Standard Detail 14-01-010

Weep Holes

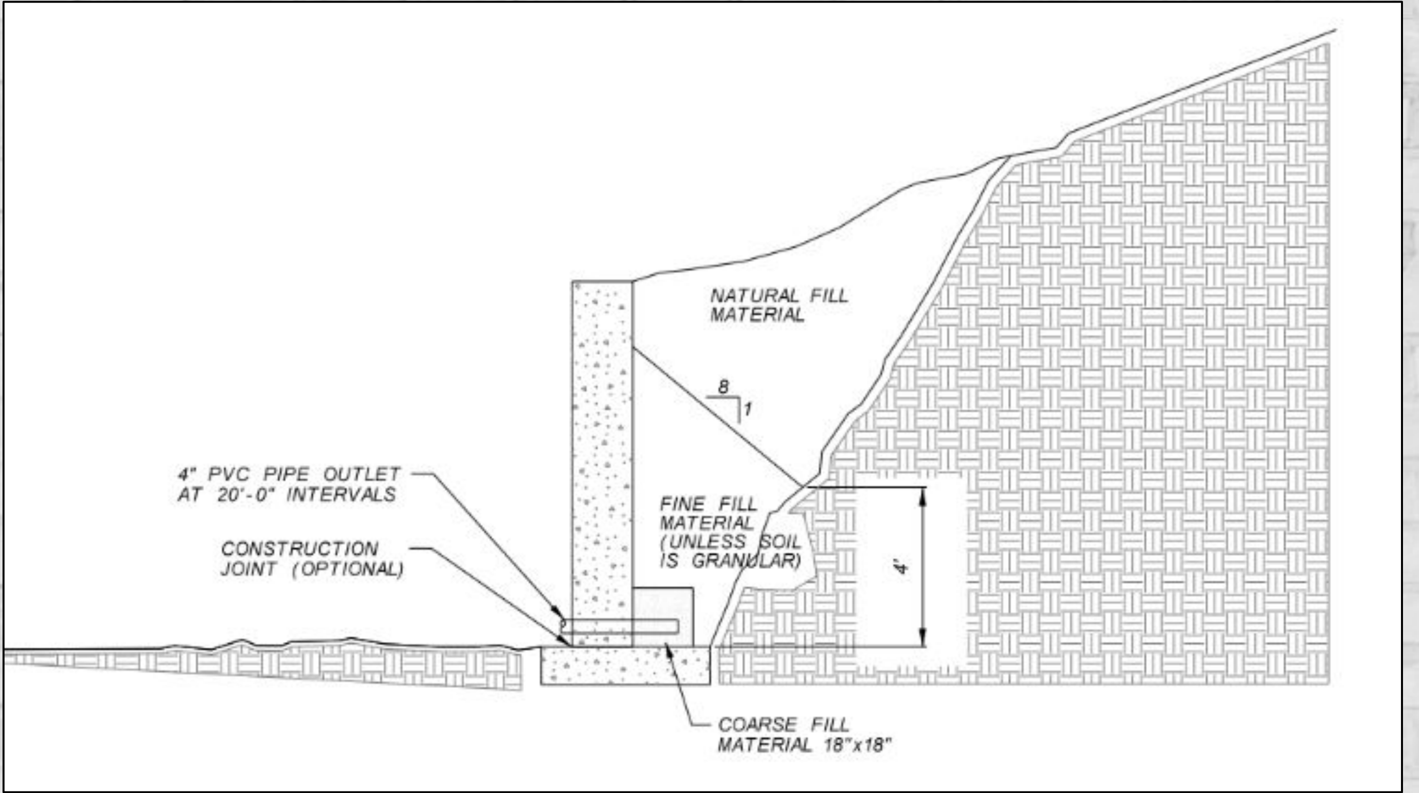


Figure 20: Maricopa Standard detail for a retaining wall [6]

Drainage for the wall will use the Maricopa design detail, as shown in Figure 16.

Weep holes:

- 4” PVC
- Spaced 20’-0” intervals
- Coarse material will be determined as a gravel or course sand.

Impacts

Environmental

- Concrete is a primary producer of CO_2 and produces greenhouse gases. (Concrete footing)
- Construction process of the wall will cause waste and temporary pollution on to surrounding population.

Social

- Flagstaff Urban Trail System (FUTS) path extension with handrail on top of wall to provide safety for pedestrians.
- Increase in FUTS trail use.
- Decreased amount of traffic around Northern Arizona University.

Economic

- Support local masonry block manufacture in Flagstaff using CMU for wall construction
- Local contractors for wall construction.
- Increase in growth for 4th Street and Route 66 local Flagstaff businesses and surrounding businesses.

EOPC - Engineers Opinion of Probable Cost

Table 19: EOPC Cost Estimate

EOPC- Engineering Opinion of Proposed Construction					
Item Number	**Quantity**	**Units**	**Description of Item**	**Unit Cost**	**Cost**
Dirt Excavation and Demolition					
1	$2,778	CY	Dirt Excavation and Removal	$25	$69,444
				Total	$69,444
Retaining Wall Proposed Cost and Items					
2	$833	CY	Concrete for Foundation	$750	$624,750
3	$38,063	LF	#7 Rebar	$15	$570,938
4	$10,500	SF	Unit Masonry Assemblies (Split Face 8" Thick)	$56	$588,000
5	$1,500	LF	Cost of FUTS Handrail	$95	$136,500
6	$75	LF	PVC Pipe for Weep holes (4")	$2	$150
7	$3,375	CY	Granular Coarse Fill (18'X18") along wall	$25	$84,375
				Total	$2,004,713
				Total Cost:	$2,074,157

*All estimates were determined off of ADOT Bid Numbers (Estimated engineering construction cost C2E2)

Project Hours
(Proposed vs Actual)

Table 20: Proposed Staffing Hours

Projected				
Task	Hours Per Staff Member			Total Hours
	Sr. ENG	Assoc. ENG	EIT	
1.0 Site Investigation	3	3	3	9
2.0 Field Sampling				
2.1 Field Work Plan	1	1	7	9
2.2 Field Work	1	9	20	30
3.0 Geotechnical Analysis				
3.1 Sieve Analysis	1	2	15	18
3.2 Hydrometer	1	2	15	18
3.3 Atterberg Limits	1	2	15	18
3.4 Sand-Cone Test	1	2	15	18
3.5 Tri-axial	1	2	15	18
3.6 Consolidation	1	2	15	18
4.0 Hydrology	4	12	32	48
5.0 Hydraulics	3	9	24	36
6.0 Wall Design Process				
6.1 Wall Designs	4	48	38	90
6.2 Plan and Profiles	1	1	7	9
6.3 Final Wall Design Selection	2	6	1	9
7.0 Impacts	3	3	3	9
8.0 Project Management	64	78	131	273
PROJECT TOTALS	92	182	356	630

Table 21: Actual Staffing Hours

Actual (sum of all hours per position)				
Task	Hours Per Staff Member			Total Hours
	Sr. ENG	Assoc. ENG	EIT	
1.0 Site Investigation	1	1	1	3
2.0 Field Sampling				
2.1 Field Work Plan	2	1	9	12
2.2 Field Work	0	0	5.5	5.5
3.0 Geotechnical Analysis				
3.1 Sieve Analysis	0	2	8	10
3.2 Hydrometer	3	1	10.5	14.5
3.3 Atterberg Limits	0	2	9	11
3.4 Sand-Cone Test	4	2	8	14
3.5 Tri-axial	3	9	13	25
3.6 Consolidation	3	5	14.5	22.5
3.7 XRF Contaminats Test	0	0	6	6
3.8 Direct Shear	0	0	7	7
4.0 Hydrology	0	2	10	12
5.0 Hydraulics	0	0	6	6
6.0 Wall Design Process				
6.1 Wall Designs	6	15.5	24	45.5
6.2 Plan and Profiles	0	5	15	20
6.3 Final Wall Design Selection	0	0	4	4
7.0 Impacts	0	0	0	0
8.0 Project Management	39.5	67.5	111	218
PROJECT TOTALS	61.5	113	261.5	436

Engineering Summary of Cost

Table 22: Proposed cost of engineering service

Item	Description	Cost per Unit	Number of Units	Units	Cost
1.0 Personnel:	Sr. Eng.	$200.00	92	Hours	$18,400.00
	Assoc. Eng.	$140.00	182	Hours	$25,480.00
	EIT	$90.00	356	Hours	$32,040.00
	Total Personnel:				$75,920.00
2.0 Supplies:	Lab Rental	$100.00	108	Hours	$10,800.00
3.0 Total					$86,720.00

Table 23: Actual cost of engineering service

Item	Description	Cost per Unit	Number of Units	Units	Cost
1.0 Personnel:	Sr. Eng.	$200.00	67.5	Hours	$13,500.00
	Assoc. Eng.	$140.00	126	Hours	$17,640.00
	EIT	$90.00	282.5	Hours	$25,425.00
	Total Personnel:				$56,565.00
2.0 Supplies:	Lab Rental	$100.00	42.5	Hours	$4,250.00
3.0 Total					$60,815.00

Schedule

- Proposed schedule tasks located above with lighter color
- Actual schedule tasks located below with darker color

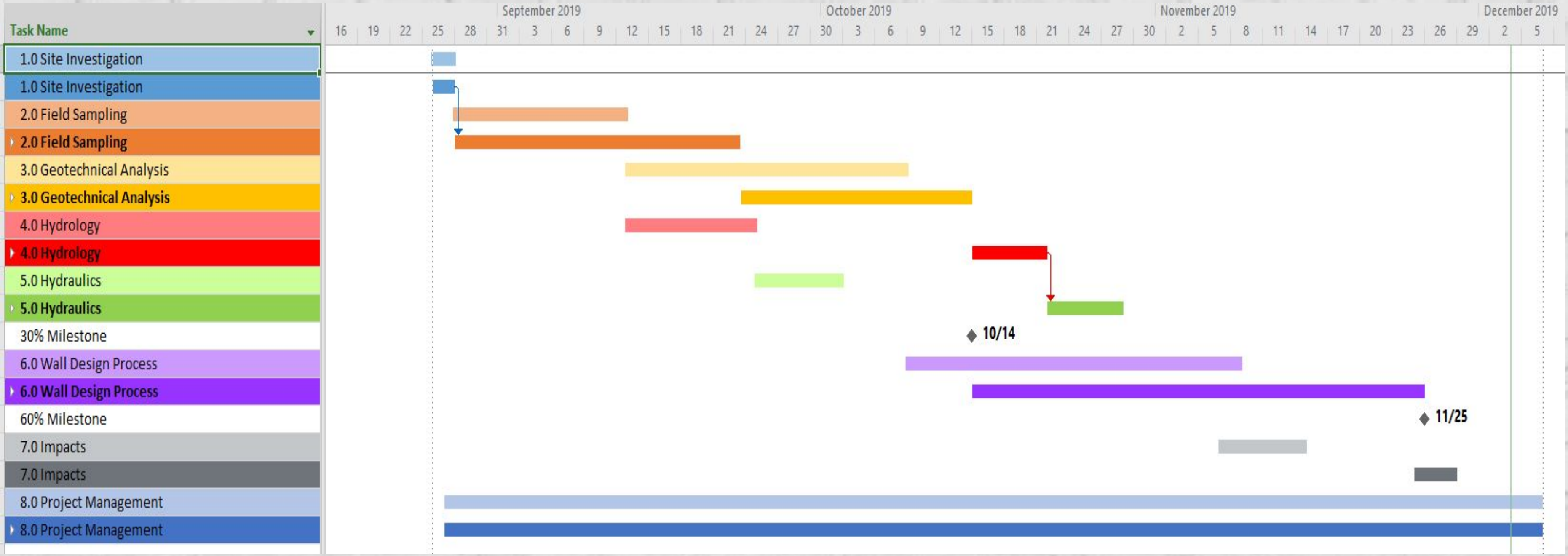


Figure 21: Schedule Edited and Updated

References

[1] Gismaps.coconino.az.gov. (2019). *Coconino Parcel Viewer*. [online] Available at: https://gismaps.coconino.az.gov/parcelviewer/ [Accessed 25 Feb. 2019].

[2] Earth.google.com. (2019). *Google Earth*. [online] Available at: https://earth.google.com/web/ [Accessed 25 Feb. 2019].

[3] Compass.astm.org. (2019). *ASTM International - Compass Login*. [online] Available at: https://compass.astm.org/EDIT/html_annot.cgi?D4767+11 [Accessed 28 Feb. 2019].

[4] N. Braja M. Das, Principles of Foundation Engineering, 9 ed., Boston, Massachusetts: Cenage, 2017.

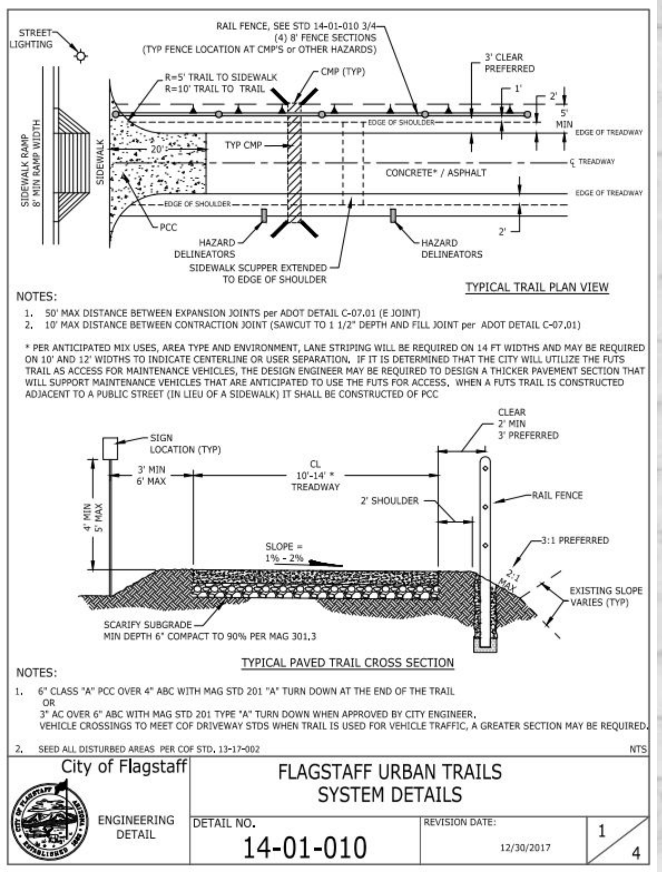
[5] Arizona Department of Environmental Quality, "Department of Envirnmental Quality - Remedial Action," 31 March 2009. [Online]. Available: https://apps.azsos.gov/public_services/Title_18/18-07.pdf.

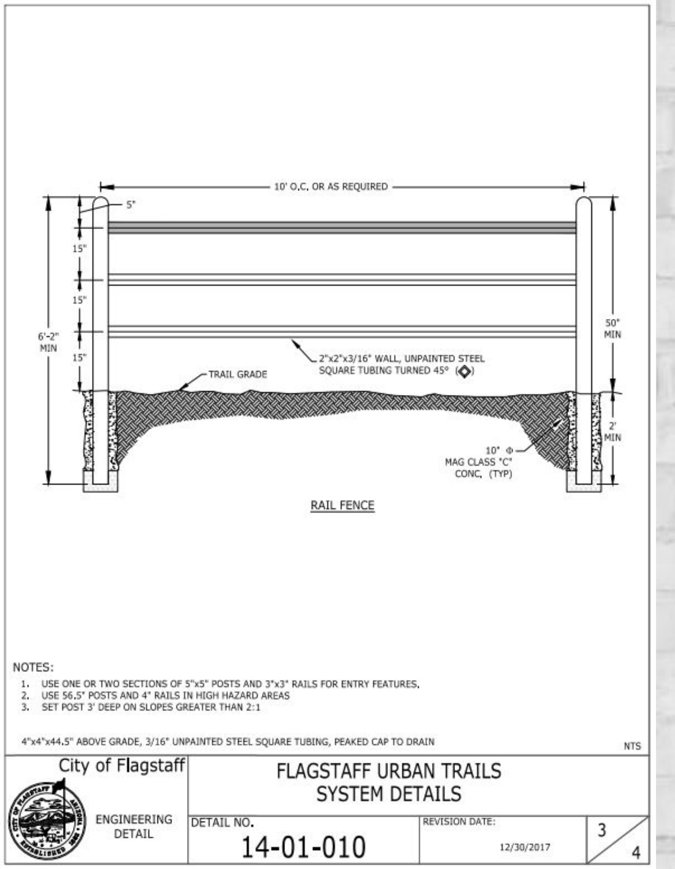
[6] Standard Procedures & Details | Maricopa County, AZ", *Maricopa.gov*, 2019. [Online]. Available: https://www.maricopa.gov/624/Standard-Procedures-Details. [Accessed: 16- Oct- 2019].

[7]"StreamStats", *Streamstats.usgs.gov*, 2019. [Online]. Available: https://streamstats.usgs.gov/ss/. [Accessed: 16- Oct- 2019].

Questions?

FUTS Railing Standards





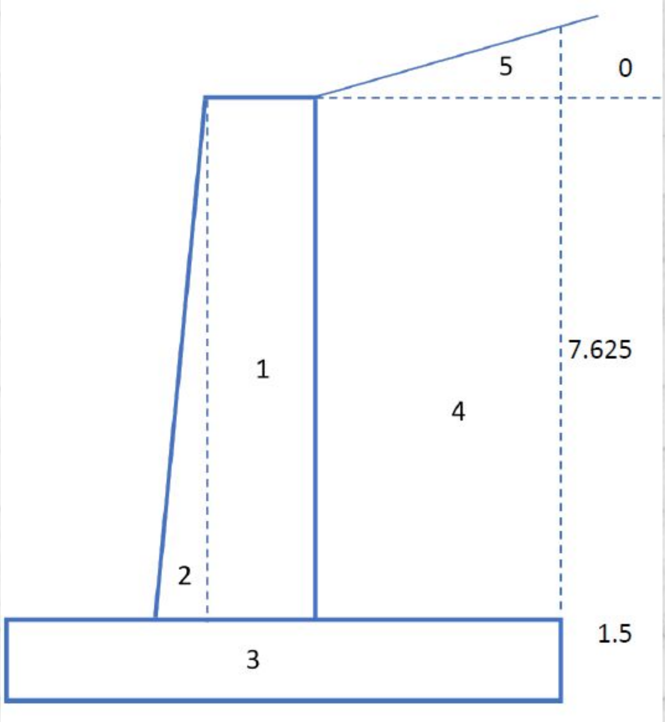
Reinforcement Calculations

M (lb-ft/ft)	16413.036
M (kip-ft/ft)	16.413036
la (in)	3.4
As (in^2)	1.072747451
J	0.865906569
la (in)	3.463626275
As (in^2)	1.053041248
one #7 rebar in every cell	

qmin (psf)	158.015
qmax (psf)	2100.208
m	194.2193
q (psf)	1879.68817
P1 (lb/ft)	2134.229276
P2 (lb/ft)	125.1909453
P (lb/ft)	2259.420221
x (ft)	0.567708333
Ma (lb-ft)	1282.691688
M (lb-ft)	2052.306701
M (kip-ft)	2.052306701
la (in)	11.9
As (in^2)	0.038325055
a (in)	0.0901766
J	0.996779407
la (in)	13.9549117
As (in^2)	0.032681551
Rebar not needed	

qmin (psf)	158.015
qmax (psf)	2100.208
m	194.2193
q (psf)	1879.68817
P1 (lb/ft)	1400.737135
P2 (lb/ft)	7630.957643
P (lb/ft)	9031.694779
x (ft)	2.5
Ma (lb-ft)	57482.97406
M (lb-ft)	91972.7585
M (kip-ft)	91.9727585
la (in)	11.9
As (in^2)	1.71751183
a (in)	4.041204306
J	0.855671275
la (in)	11.97939785
As (in^2)	1.706128391
3 #7 rebar per foot	

Tallest Wall Design Equation List



Formulas				Notes
1	Rankine Coeffiecient of Active Pressure	ka =	tan2(45-ϕ'/2)	
2	Active Stress	σ'a =	γ*H*ka	C=0
3	Resultant Active Pressure	Pa=	σ'a *H*.5+Pq	
4	Applied Vertical Pressure of Soil	Pv=	Pa*sin(α)	
5	Applied Horizontal Soil Pressure	PH =	Pa*cos(α)	
6	Factor of Safety for Overturning	FS overturn=	Mr/Md ≥ 2	
7	Sum of Resistive Forces	Mr=	ΣV*(Marm)+Pv*(Marm)	
8	Driving Moment	Md=	PH*(H/3)	
9	Net Moment	MN=	Mr-Md	
10	Factor of Safety for Sliding	FS Sliding=	Fr/Fd ≥ 1.5	
11	Resisting Force	Fr=	fr+fc+PP	fc=0
12	Driving Force	Fd=	PH	
13	Resultant Force of Pv and Sum of Weight	fr=	(Pv+ΣV)*tanδ	
14	Soil-Pile Friction Angle	δ=	2/3*ϕ'	
15	Coefficient of Friction	Coefficient=	tan(δ)	
16	Resultant Passive Pressure	PP=	σ'P/2*Df	
17	Passive Stress	σ'P =	kP*γ*Df	C=0
18	Rankine Coefficient of Passive Pressure	kP=	tan2(45+ϕ'/2)	
19	Factor of Safety for Bearing	FS Bearing=	qu/qmax ≥ 3	
20	Bearing Pressure on Toe	qmax =	ΣV/B*(1+6e/B)	
21	Eccentrictiy of Load	e=	B/2-MN/ΣV	
22	Bearing Pressure on Heel	qmin=	ΣV/B*(1-6e/B)	
23	Unconfined Compressive Strength	qu=	c'*Nc*Fcd*Fci+q*Nq*Fqd*Fqi+0.5*γ*B'*Nγ*Fγd*Fγi	
24	Bearing Pressure	q=	γ*D	
25	Effective Base Dimension	B'=	B-2*e	
26	Cohesion	c'=	0	
27	Bearing Capacity Factor	Nc=	60.78	For ϕ' = 37.9 degrees (values interpolated)
28	Bearing Capacity Factor	Nq=	48.33	
29	Bearing Capacity Factor	Nγ=	76.85	
30	depth Factor	Fcd=	Fqd-[(1-Fqd)/(Nctan(ϕ'))]	For Df/B ≤ 1 and ϕ' > 0
31	depth Factor	Fγd=	1	
32	depth Factor	Fqd=	1+2tanϕ'(1-sinϕ')2Df/B	
33	Angle of soil at top of wall	β=	arctan(PH/ΣV)	
34	Inclination Factor	Fci=Fqi=	(1-β/90)2	For β=29.93 degrees
35	Inclination Factor	Fγi=	(1-β/ϕ')2	
36	Weight of Area 1	V1=	A1*γ (concrete)	
37	Weight of Area 2	V2=	A2*γ (concrete)	
38	Weight of Area 3	V3=	A3*γ (concrete)	
39	Weight of Area 3	V4=	A4*γ (soil)	
40	Weight of Area 4	V5=	A5*γ (soil)	
41	Weight of Area 5	ΣV=	V1+V2+V3+V4+V5	
42	Allowable Soil Bearing Pressure	qall=	qu/FS	1817.0388

Determined Variable Values:

ϕ'	37.900	degrees	
ϕ'	0.661	radians	
γ (soil)	109.370	pcf	
γ (concrete)	150.000	pcf	
γ (normal CMU)	125.000	pcf	
H	9.125	feet	
Df	5.000	feet	
ka	0.239		
α	0.000	degrees	
α	0.000	radians	
σ'a	238.461	psf	
Pa	4887.978	lbs/ft	
Pq (surcharge)	3800.000	lbs/ft	
Pv	0.000	lbs/ft	
PH	4887.978	lbs/ft	
A1	4.845	ft^2	
A3	15.000	ft^2	
A4	67.592	ft^2	
			Moment arm
V1	605.632	lbs/ft	0.81770833 ft
V3	2250.000	lbs/ft	5 ft
V4	7392.517	lbs/ft	5.56770833 ft
ΣV	10248.148	lbs/ft	
Mr	52904.606	lb-ft/ft	
Md	14867.599	lb-ft/ft	
MN	38037.007	lb-ft/ft	
FSoverturn	3.558	≥3	

δ	25.267	degrees
δ	0.441	radians
σ'P	2288.567	psf
kP	4.185	
B	10.000	feet
e	1.288	feet
B'	7.423	feet
β	25.49937075	degrees
β	0.4450479768	radians
qu	18486.560	psf
qmax	1817.039	psf
qmin	232.591	psf
q	546.850	psf
Fcd	1.118	
Fγd	1.000	
Fqd	1.116	
Fci=Fqi	0.514	
Fγi	0.107	
FSbearing	10.174	≥3

fr	4836.985	
fc	0.000	
PP	5721.418	lbs/ft
Fr	10558.40:	
Fd	4887.978	lbs/ft
FSsliding	2.160	≥1.5